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The report ~~D~~escribes the procedures for high and low temperature test of vehicles in test chambers and operational conditions. It ~~D~~iscusses related tests such as temperature shock. The report also Addresses requirements of MIL-STD-810C and AR 70-38, ~~D~~iscusses high and low temperature effects and provides rationale for test temperatures.

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US ARMY TEST AND EVALUATION COMMAND
DEVELOPMENT TEST II (EP) - COMMON TEST OPERATIONS PROCEDURES

DRSTE-RP-702-101
Test Operations Procedures 2-2-816 21 March 1979
AD No.

HIGH- AND LOW-TEMPERATURE TESTS OF VEHICLES

1. SCOPE. This document provides guidance for planning and conducting tests of Army automotive vehicles to determine their ability to meet the high- and low-temperature requirements of ROCs, DPs, or other guidance documents. Tests are mostly conducted in chambers and are applicable to development tests I, II, and IIa and customer tests. The rationale for the temperatures is in appendix A.

2. FACILITIES AND INSTRUMENTATION.

a. The facilities available for high- and low-temperature tests of vehicles are described in DARCOM Pamphlet, DARCOM-P-70-1, Research and Development DARCOM Test Facilities Register.

b. Air temperatures at the chamber control sensors will be maintained at the prescribed temperatures $\pm$ 1.4° C (2.5° F).

3. PREPARATION FOR TEST. Before extreme-temperature testing the performance of the vehicle and all components that are to be evaluated at extreme temperatures will first be evaluated under normal ambient conditions to obtain baseline data. Before being placed in the chamber, the vehicle must be prepared for the extreme temperatures in accordance with the instructions supplied. For cold testing, for example, the concern is with cold-weather fuels, lubricants, antifreezes, and kits.

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4. TEST CONTROLS. The safety of test operations is an important consideration in the chamber testing of vehicles. Safety precautions must be detailed in suitable SOPs before operations begin, and are beyond the scope of this TOP. Suffice it to say that safety actions include venting the vehicle exhaust through a flexible hose to the outside of the chamber, monitoring the chamber for carbon monoxide and for gasoline fumes, adequate training of personnel, adequate control and health assurances relative to visitors, adequate clothing and cold-weather precautions for personnel during cold tests, adequate precautions against heat for personnel during high-temperature tests, prior safety evaluation of ammunition (TOP/MTP 4-2-504 1/), prior safety evaluation of weapons (TOP 3-2-504 2/ or 3-2-805 3/), and prior safety evaluation of vehicle, fire control, and components.

5. PERFORMANCE TESTS.

5.1 Low-Temperature Tests (Operation and Storage). The low-temperature requirements are in the ROC, DP, or other guidance document, as amended or clarified by the directive. The requirements for low-temperature performance are not consistent for all vehicles; the temperature at which certain kits or aids may be introduced often varies. The guidance document must be examined to determine the exact cold-weather performance requirements of each vehicle.

5.1.1 Method. Use lubricants, fuel, hydraulic oil, etc., as prescribed in the lubrication order for low temperature, this order is divided into phases, with vehicle performance being examined at several increasingly colder conditions. Fuels should be analyzed to determine that they meet the specification criteria, especially with regard to cloud point. While ROCs and DPs may specify the extreme low temperature, the intermediate temperatures have been selected (table 1) based on experience and available comparative data. Once the vehicle has been placed in the cold chamber it will usually occupy the chamber until all low-temperature testing is complete. Exceptions usually are a result of vehicle failures that require repairs. Although the procedures below discuss only five different temperature levels - cold ambient (below -18° C (0° F)), -18° C (0° F), -33° C (-28° F), -46° C (-50° F), and -51° C (-60° F) - it is sometimes desirable to add a -23° C (-10° F) test following the -18° C test.

5.1.2 Cold Ambient Outdoor Test. This test takes advantage of opportune weather conditions (at sites such as APG). Use this test to provide data under conditions difficult to duplicate in environmental chambers and to give indications of possible problem areas that may be encountered in

1/ TOP/MTP 4-2-504, Safety Evaluation - Arty, Mortar, and Recoilless Rifle Ammunition.
2/ TOP 3-2-504, Safety Evaluation of Hand and Shoulder Weapons.
3/ TOP 3-2-805, Safety Evaluation of Cannon and Recoilless Weapons.

chambers. The colder the weather the better; generally, no significant amount of sun can be tolerated. To achieve such conditions it may be necessary to conduct tests at night. Tests that should be conducted if conditions are favorable are in table 1. Due to the frequency with which these weather conditions are encountered when the vehicle is in the hands of troops, problems during this test must be looked upon as serious; corrective action must be taken, when possible, before placing the item in the cold chamber. Cold ambient tests are conducted below the freezing point.

If no suitable low ambient temperatures are feasible before the start of the chamber tests, an additional chamber test at -1° C (30° F) is added at the beginning of chamber operations. Should suitable weather conditions develop only after completion of the chamber test, an abbreviated cold outdoor test will still be performed.

5.1.3 -18° C (0° F) Chamber Test. This test is concerned with performance in a chamber at cold temperatures that are more prevalent than the extreme temperatures. Because of the confining nature of the chamber, all the components of large equipment cannot be properly exercised (bulldozer operation, movement of booms, etc.). Perform exercising to the extent possible. Tests to be conducted at -18° C are listed in table 1. As with all cold tests, thermocouples will be attached to critical locations on the vehicle. Temperature stabilization will be considered to have been achieved when (as prescribed in MIL-STD-810C [4/]) the temperature of the component with the greatest thermal lag comes within 2.8° C (5° F) of the prescribed temperature. All portions of the vehicle will be open, including doors, engine hood, etc., to facilitate airflow and reduce the time for cooling. Theoretically it is possible to reduce cooling time further by conducting temperature soaking at a temperature slightly below the planned temperature (for example, -20° to -23° C (-5° to -10° F) instead of -18° C (0° F)) and, as the correct materiel temperature is approached, readjusting the air temperature to the correct temperature. This approach is usually not recommended, however, because the time saved is seldom worth the extra attention required. The vehicle will normally be winterized, but no kits or outside aids for starting and operation will be used.

5.1.4 -33° C (-28° F) Chamber Test. Hold the chamber temperature at -33° C to satisfy the storage requirements for Basic Cold of AR 70-38. After the vehicle is stabilized at -33° C for 24 hours, vehicle performance will commence. The tests to be conducted are listed in table 1. The -33° C temperature is considered close enough to the -32° C (-25° F) operational temperature to satisfy that condition.

4/ MIL-STD-810C, Environmental Test Methods.

TABLE 1. LOW-TEMPERATURE TESTS

Test	Cold Ambient	-18° C	-33° C Basic Cold	-46° C Cold	-51° C Severe Cold
Cold starting and warm-up (TOP 2-2-650)	X	X	X	X	Para 5.1.4
Heater operation (TOP 2-2-708)	X	X	X	X	Para 5.1.6
Human factors (TOP 1-2-610)	X	-	X	X	Para 5.1.6
Stabilization systems (TOP 3-2-602)	X	-	X	X	Para 5.1.6
Weapon firing, performance	X	X	X	X	para 5.1.6
Weapon firing, safety	-	-	-	X[1]	X[1]
Viewing and optical equipment, defrosting and operation	X	X	X	X	Para 5.1.6
Exercising of all components and ancillary equipment, switches, valves, and anything movable	X	X[2]	X[2]	X[2]	para 5.1.6
Electrical checkout	X	X	X	X	-
Operation over frozen ground	X[3]	-	-	-	-
Operation in snow and during snowstorms	X[3]	-	-	-	-
Low-temperature storage	-	-	X	X[4]	X (48 hours at temp)
Freezing rain (TOP 2-2-815)	-	X	-	-	-

[1]Vehicles will be completely cold for a safety test. For the "basic cold" requirement, safety testing of weapons is done at -46° C. For the "cold" or "severe cold" requirement, safety testing is at -51° C.
[2]Within facility limitations, short forward and backward movements and operation of ancillary equipment, as appropriate, will be included.
[3]As weather conditions permit.
[4]The operational tests will satisfy the requirements of a storage test.

5.1.5 -46° C (-50° F) Chamber Test. Use test operations at -46° C to meet the "Cold" climate operational requirements of AR 70-38 5/ when so required by the ROC or DP. AR 70-38 permits the use of kits, such as auxiliary power sources, at this temperature; these will be used in the test as appropriate. The lowering of the temperature from -32° to -46° C will be accomplished in much the same way as in 5.1.3 above. Tests to be conducted at -46° C are listed in table 1. Because of the time required to conduct the performance test, this testing will be assumed to cover the storage test at -46° C as well.

5.1.6 -51° C (-60° F) Chamber Test. Use the -51° C chamber test only as a safety test for weapons unless the ROC or DP specifically requires storage or storage and operation, in accordance with the "Severe Cold" category of AR 70-38. For materiel that is expected to perform adequately at this temperature, specialized kits and aids may exist in considerable numbers. In addition, in some cases a failure that would be considered a deficiency at -46° C would only be considered a shortcoming at -51° C. To satisfy a requirement for operation at -51° C the tests to be conducted at -51° C will be the same as those at -46° C as shown in table 1. If a storage test or a weapon safety test is required at -51° C, but not a performance test, a complete performance test is first made at -46° C; then the temperature is reduced to -51° C and the vehicle held at this temperature for 48 hours after stabilization. Following storage at -51° C the vehicle will be restored to -46° C and a performance check made at -46° C.

5.1.7 Data Required. The data to be recorded will involve the same data parameters as those for comparable tests conducted at normal temperature. Particular attention will be paid to probable problem areas listed in appendix B.

5.2 High-Temperature Tests (Operation and Storage).

5.2.1 Standards. The high-temperature requirements are in the ROC, DP, or other guidance document as amended or clarified by the directive. Although all vehicles must be able to perform under the Basic Hot conditions of AR 70-38, most vehicles must also perform under Hot-Dry conditions, which are somewhat more severe.

5.2.2 Method. Before being subjected to a high-temperature test the vehicle must have been subjected to comparable tests under normal conditions. Lubricants, fuel, coolants, hydraulic oil, etc., must be as prescribed in the lubrication orders for high-temperature conditions. Thermocouples must be installed at all points where temperatures are required.

5/ AR 70-38, Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions, 1978.

5.2.3 Hot Ambient, Outdoor Test. Conduct tests of this type under the hottest natural conditions available. Tests will be conducted under full sun and preferably when the air temperature is above 32° C (90° F). Tests may include:

Engine and power train cooling (TOP/MTP 2-2-607) 6/.
Air conditioners (TOP/MTP 2-2-713) 7/.
Human factors (TOP 1-2-610)
Braking (TOP/MTP 2-2-608) 9/.
Weapon firing performance.
Weapon firing safety.
Exercising all components and ancillary equipment.
Checkout of all electrically operated equipment and lights.

5.2.4 Chamber Test. The test described below covers both the performance test and the storage test. The rationale for the temperatures selected and for not using solar radiation is in appendix A.

NOTE: This does not preclude the use of the solar radiation chamber for simulated exposures to the desert sun of vehicle components, mounted to the outside of the vehicle, which may be heat sensitive. See paragraph 5.3f for procedures.

a. Place the vehicle in a chamber and raise the temperature of the chamber to the storage temperature prescribed in table A-2 and hold for 24 hours after stabilization. Temperature stabilization is considered to have been achieved when (as prescribed by MIL-STD-810C) the temperature of the component with the greatest thermal lag comes within 2° C (3.5° F) of the prescribed temperature. Thermocouples will be placed at critical locations for this purpose. Once test operations begin, pertinent temperatures will be recorded continuously or at intervals of not greater than 5 minutes.

b. A test suitable for most vehicles follows: start the engine and immediately set the chamber at the reduced temperature shown in table A-2. The vehicle is then operated at various speeds from idle to maximum governed for a total of 1 hour. Ventilators and air conditioners, if any, must be in operation. During this hour all components will be actuated in turn; this includes engaging and disengaging all clutches instantly at maximum governed engine speed, actuation of brake controls, and movement of all powered components to cover all extremes of movement. At the end of 1 hour the engine will be stopped. It is restarted 5 minutes later and operated for 5 minutes without load, stopped, restarted in

6/ TOP/MTP 2-2-607, Engine and Power Train Cooling Systems (Vehicle).
7/ TOP 2-2-713, Air Conditioners.
8/ TOP 1-2-610, Human Factors Engineering.
9/ TOP/MTP 2-2-608, Braking, Wheeled Vehicles.

30 seconds, and operated for a second hour. During this period the vehicle will be moved forward and backward and the wheels turned to each extreme, as possible within the confines of the chamber. The engine will be stopped after the second 1-hour period; restarting will be attempted immediately, and the engine run without load for 5 minutes.

(1) There will usually be no need to impose a full load on a vehicle by connecting a dynamometer to the power train because to do so would impose an unnaturally severe condition: normally when a vehicle is under full load it is moving forward, benefiting from the cooling air through which it moves. A vehicle idling under hot conditions with all equipment operating will test the cooling and transmission systems adequately for purposes of the Development Test II. If high-temperature tests under load are required, they can be done outdoors at Yuma Proving Ground, or at APG using a dynamometer and fans to create airflow.

(2) For vehicles that have weapons, the weapons will be fired in accordance with procedures in the TOPs/MTPs of volumes II and III. All ammunition will have previously successfully passed the safety evaluation of TOP 4-2-504, which includes a high-temperature test. Weapons will have undergone a safety evaluation in accordance with TOP 3-2-504 or TOP 3-2-805 at ambient temperature. Sometimes the weapon tests will follow the automotive tests while the vehicle is still in the chamber; often, however, the weapon tests will be separate from the automotive test.

(3) The effect of temperature on human factors will be observed and recorded in accordance with paragraph 6.2.4 of TOP 1-2-610.

(4) Air conditioners will be tested in accordance with TOP 2-2-713.

5.2.5 Data Required.

a. Temperatures. While the equipment is operating, temperatures will be recorded as follows:

(1) Engine-coolant temperatures in engine-coolant-jacket discharge pipe and coolant inlet to the engine.

(2) Engine-lubricating-oil temperature in the oil gallery, oil sump, and oil-cooler sump (or line entering the cooler).

(3) Torque-converter-oil temperature at the outlet from the converter to the oil cooler and transmission sump.

(4) Hydraulic-oil temperature at the midpoint of the reservoir.

(5) Battery electrolyte temperature.

(6) Fuel-tank temperature.

(7) Air temperature in suitable locations in the chamber.

(8) Air temperature inside the vehicle at appropriate crew locations.

(9) Temperatures at other locations that are significant to the specialized nature of the equipment (e.g., thermocouples in the air discharge and lubricant of a compressor).

b. Component performance. Data adequate to compare component performance at high temperature against performance at normal temperatures will be recorded. Included are: electrical system, communication system, lights, viewing devices, ventilating system, etc.

c. Weapon performance. Data adequate to compare the performance of the weapon system against the DP or ROC and the performance at normal temperature will be recorded. Included are: stabilization system, electrical firing system, fire control system, elevation and depression, loading, secondary weapons, etc.

d. Human factors. The influence of temperature on the ability of the crew to perform its functions will be recorded.

e. Heat damage. The effect of the high temperature on materials, seals, lubricants (leakage), etc., will be recorded.

5.3 Other Temperature-Related Tests. In addition to stabilized high or low temperatures, there are temperature-related factors which should be considered.

a. Temperature shock. The transition, from one extreme temperature to the opposite extreme in a short period, is a test condition generally found in multicommodity specifications such as MIL-STD-810C, method 503. Though this situation could conceivably be approximated - for example, by driving a vehicle out of a cold room into the open on a hot, sunny day - the need for such a test is doubtful. The likelihood of large items such as vehicles having large temperature changes in short periods during their life cycle is remote.

b. Snow load. Snow load is covered in AR 70-38. The ability of vehicles to withstand snow loads can be determined by placing an appropriate number and weight of sandbags on questionable areas of the vehicles. Assuming that snow is cleared between snowfalls, the pressure of snow to be simulated is 960 pascals (20 lb/ft^2).

c. Snow mobility. Tests to evaluate snow mobility must await opportune snowstorms in continental United States or at the Cold Regions Test Center.

d. Freezing rain. A freezing-rain test, sometimes called an icing test, will be part of the low-temperature testing of vehicles and is discussed in TOP 2-2-815 10/.

e. Falling and blowing snow. Falling and blowing snow are described in AR 70-38. Snow can jam moving parts, reduce visibility through snow deposits on optical devices, cause ice deposits through melting and freezing, etc. Snow making equipment is available in Cold Room 3 for static testing. Performance tests of this type must await opportune weather conditions in continental United States or at the Cold Regions Test Center.

f. Solar radiation. The need for a solar radiation test of vehicle components must be determined on an individual basis. The key question is: are there exposed heat-sensitive components that will face the sun? If so, the component should be removed from the vehicle and exposed in a solar radiation chamber that can simulate the conditions of AR 70-38. The resultant temperatures sometimes reach 71° to 82° C (160° to 180° F). Solar radiation tests are covered by TOP/MTP 4-2-826 11/. Five 24-hour cycles will be used unless otherwise justified.

g. High humidity - high temperature. This test usually will follow the high-humidity steady-state test of TOP/MTP 4-2-820 12/, which requires 49° C (120° F) for 360 hours followed by a return to standard conditions (25° C (77° F) and less than 90% relative humidity) where the item is examined and operated. Also suitable is the cycling test of MIL-STD-810C, method 507, procedure V, which calls for cycling between 41° and 21° C (105° and 70° F) for 480 hours at high humidities. These high-humidity tests can produce corrosion, electrical malfunctions, swelling of nonmetallic materials, loss of insulating qualities, deterioration of hygroscopic materials, etc. Although not specifically a fungus test, this test may produce fungus growth when the proper spores and supporting materials are present.

5.4 Tests at Eglin AFB Climatic Hangar. The capabilities of the hangar are described in appendix C. This chamber will be used when there is a requirement for a considerable amount of movement of the vehicle or available DARCOM facilities are not large enough. Only small caliber weapons may be fired from within the chamber and firing is only to check whether the weapon is functioning properly. The cost and time involved in testing vehicles at Eglin must be fully considered before making the decision to use this facility.

10/ TOP 2-2-815, Rain and Freezing Rain.
11/ TOP/MTP 4-2-826, Solar Radiation Tests.
12/ TOP/MTP 4-2-820, Humidity Tests.

6. DATA REDUCTION AND PRESENTATION. A comparison will be made between performance at low and high temperatures and performance at normal temperatures. Where failures occur, statements must be made as to the next milder condition under which no failure occurs, in accordance with DARCOM supplement 1 to AR 70-10 13/. In addition, where failures occur, possible corrective action or precautions that the crew should take must be mentioned.

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13/ DARCOM Supplement 1 to AR 70-10, Test and Evaluation During Research and Development of Materiel.

APPENDIX A
RATIONALE FOR TEMPERATURES

1. Effects of Extreme Temperatures on Vehicles. There are a large number of possible effects of high- and low-temperature extremes on vehicles, related to both expansion and contraction and to changing the properties of matter. A listing of such effects is in appendix B.

2. Applicability of AR 70-38. Army equipment must be able to support military operations during any season and in nearly all parts of the world. In any extreme climatic area, ambient temperature is the most important of the associated environments. Insofar as the Army is concerned, AR 70-38 (Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditons) provides the overriding guidance on climatic conditions. The AR prescribes policies, responsibilities, and information for the realistic simulation of climatic conditions during RDTE.

AR 70-38 divides the world into four climatic categories, the one designated "Basic" being mandatory for all general-purpose equipment. As a minimum, Army vehicles must be capable of ready operation without kits or assistance in Basic climates. In many cases, however, the requirements document will require that the vehicle also be capable of operation, possibly with the assistance of kits, in other climatic categories of AR 70-38 which may include Hot, Cold, and Severe Cold. Severe Cold is rarely stipulated; no assumption is made that it is applicable unless so specified.

AR 70-38 states that for most climatic categories the extreme values therein are exceeded not more than one percent of the hours in the most severe month in an average year for that climatic area. On rare occasions there will be temperatures that exceed (colder or hotter) the extremes stipulated in AR 70-38; under those rare conditions there is no requirement that the vehicle be able to operate. This one-percent risk policy the Army is willing to accept. In addition to operating conditions, AR 70-38 provides the extremes for storage and transit conditions. Insofar as vehicle testing is concerned, the vehicle is expected to withstand the storage and transit extreme (e.g., the battery should not burst from freezing) required by the DP or ROC, start and operate for a brief period under the operating (or operational) extremes. (It is assumed that the vehicle may go from storage immediately to operation.)

AR 70-38 provides extreme temperatures covering the 24-hour day, i.e., the diurnal extremes. These are summarized in table A-1. The temperatures in this table were recorded under specifically defined conditions and do not necessarily represent the temperature for an item of materiel or the test temperature.

TABLE A-1. CONDENSED DIURNAL TEMPERATURE EXTREMES FROM AR 70-38

Climatic Design Limits	Daily Weather Cycle (QSTAG 360 Equivalents)	Operational Conditions		Storage and Transit Conditions, Induced Air Temperature, °F (°C)
		Ambient Air Temperature, °F (°C)	Solar Radiation btu/ft^2/hr, (w/m^2)	
Hot	Hot-dry (A1)	90[a] to 120[b] (32 to 49)	0 to 355 (0 to 1120)	91[a] to 160[b] (33 to 71)
	Hot-humid (B3)	88[a] to 105[b] (31 to 41)	0 to 343 (0 to 1080)	91[a] to 160[b] (33 to 71)
Basic	Constant high humidity (B1)	Nearly constant 75 (24)	Negligible	Nearly constant 80 (27)
	Cyclic high humidity (B2)	78[a] to 95[a] (26 to 35)	0 to 307 (0 to 970)	86[a] to 145[b] (30 to 63)
	Basic hot-dry (A2)	86[a] to 110[b] (30 to 44)	0 to 355 (0 to 1120)	86[a] to 145[b] (30 to 63)
	Basic cold (C1)	- 5[b] to -25[a] (-21 to -32)	Negligible	-13[b] to -28[a] (-25 to -33)
Cold	Cold (C2)	-35[b] to -50[a] (-37 to -46)	Negligible	-35[b] to -50[a] (-37 to -46)
Severe Cold	Severe cold (C3)	-60 (Cold soak) (-51)	Negligible	-60 (-51)

[a]Nighttime low.
[b]Daytime high.

The policy of AR 70-38 is that the maximum amount of extreme climatic testing be performed in chambers, before the test items are sent to the extreme-climatic field-test sites where costs are greater, more time is required, fewer technical capabilities and facilities are available, and the extremes of climate desired are rarely obtained. Well-conducted chamber tests should uncover practically all extreme-temperature deficiencies; nevertheless, following development tests II in chambers, additional tests

are often conducted at Yuma Proving Ground for high temperatures and at the Cold Regions Test Center, Fort Greeley, AK, for low temperatures.

3. Rationale for Low-Temperature Test Conditions. The lowest temperature in any of the diurnal cycles in AR 70-38 will be used as the test temperature since (a) there is only a relatively small spread between maximum and minimum temperatures during a 24-hour period and (b) a large percentage of the time the temperature is close to the diurnal extreme. The temperatures for low-temperature tests of vehicles are in table A-2. The operational temperatures and the storage and transit temperatures are the same for low-temperature tests. (Although the storage temperature (-33° C) and operational temperature (-32° C) are different for basic cold, the difference is not great enough to justify different test temperatures.)

TABLE A-2. SELECTED TEMPERATURE EXTREMES FOR TESTING UNDER AR 70-38

Climatic Category	Vehicle	Operational Conditions Test Temperature		Storage and Transit Conditions, Test Temperature	
		°C	°F	°C	°F
Hot-dry	Trucks	60, then 49	140, then 120	60	140
	Armored	52, then 49	125, then 120	52	125
Basic hot-dry	Trucks	54, then 43	130, then 110	54	130
	Armored	46, then 43	115, then 110	46	115
Basic cold	Trucks	-33	-28	-33	- 28
	Armored	-33	-28	-33	- 28
Cold	Trucks	-46	-50	-46	- 50
	Armored	-46	-50	-46	- 50
Severe cold	Trucks	-51	-60	-51	- 60
	Armored	-51	-60	-51	- 60

According to AR 70-38, under basic cold conditions the temperature of the ground (in fact, any insulated object exposed to the open sky) will be colder than the air temperature (e.g., -37° C (-35° F) as opposed

to -32° C (-25° F). This is because the ground (or surface of an item) radiates heat to the open sky. Heat conduction will tend to reduce this effect, and for all practical purposes this temperature differential may be disregarded in tests of vehicles.

Though applicable only to human beings, windchill is a term sometimes mistakenly applied to inanimate objects. Windchill is related to the increased heat loss, or increased coldness, that human beings experience when cold air is accompanied by wind. (Windchill is covered by TOP/MTP 2-2-803.) An effect similar to windchill does occur with vehicles, however, because at a given temperature the item will tend to cool faster if there is a wind and, for example, put a heavier load on heaters. The movement of a vehicle through cold air will in effect result in the same situation. To try to simulate this condition in the chamber, it would be necessary to run the vehicle on a treadmill dynamometer and to provide a wind-tunnel arrangement to produce moving air in the chamber. The cost of such a facility has never been justified, so such a test is never conducted.

In low-temperature tests of vehicles, problem areas can often be uncovered at temperatures that are much more moderate than the extreme. If natural, subfreezing conditions happen to be available, a good opportunity is afforded for making a cold-weather check of the vehicle and for correcting difficulties without the problems - scheduling, difficult working conditions, etc. - associated with the use of chambers. In making chamber tests, the test temperature is lowered in stages, to check intermediate conditions and to overcome problems under moderate working conditions. In addition, in accordance with DARCOM guidance, it is important to know at what low temperature performance will be satisfactory if operation at the extremes is unsatisfactory.

4. Rationale for High-Temperature Test Conditions. The ambient air temperatures of table A-2 were obtained in the shade within the well-ventilated white-painted standard US Weather Bureau weather shelter. In contrast, the storage and transit high temperatures (for climatic categories hot-dry and basic hot-dry in AR 70-38) are those found, for example, near the inside top of an unventilated field storage shelter, under a tarpaulin, or in a railroad boxcar exposed to the full-sunshine conditions described under the solar radiation column.

An item in the sun will normally attain a temperature higher than the ambient air because of the heating effects of solar radiation. Certain characteristics of the test item influence the amount of heating that results from solar radiation: reflectivity of the surface, mass of the material, heat-sink qualities, and insulation of exposed component; thus, heavy tank armor will not rise in temperature as much as a thin truck roof.

The hottest environmental condition for a vehicle occurs when it sits stationary under the desert sun, with hatches, doors, and windows closed. At around 1400 to 1500 hours, the peak high-temperature storage condition would be attained. (For vehicles, storage under the open sun is more pertinent than storage in a boxcar or a shelter.) If, at this time, the crew opens the vehicle, letting in air of about 49° C (120° F), and starts and operates the vehicle and its components, the peak high-temperature operational condition will have been experienced. It is the tester's job to try to duplicate both storage and operational conditions as practicable.

To reproduce these conditions in a chamber would require that the air temperature and the intensity of the simulated solar radiation rise and fall in accordance with the diurnal cycle of AR 70-38, and that the wind velocity be 3 to 5 meters/second. Perfect simulation would, in fact, also require that the solar radiation be a correct reproduction of the solar spectrum, and that the rise of the sun in the east and the setting in the west be duplicated. The difficulties of achieving these conditions make it necessary to accept compromise test conditions. The compromise involves eliminating the solar radiation; instead, the vehicle is soaked at a uniform air temperature that results in a somewhat similar effect - i.e., the vehicle attains approximately the same temperatures, averaged over the vehicle, that would have been attained under the sun. These soaking temperatures are shown in table A-2.

Vehicles sitting buttoned up under the sun in a "Hot-Dry" climate may reach peak temperatures over the vehicle ranging from possibly 43° C (110° F) to 71° C (160° F). An analysis 14/ of temperature measurements made at Yuma Proving Ground 15/ 16/ have confirmed that the test temperature widely used in the past for high-temperature storage tests of armored vehicles is still a valid temperature. The measurements showed that 52° C (125° F) (table A-2) is about the average peak temperature for inside components in a tank when it is exposed to the "hot-dry" conditions of AR 70-38. Since trucks do not have the massive armor that is difficult to heat (as do tanks), the temperature of truck components would rise to higher average temperatures when exposed to the same high-temperature condition as tank components. While data on truck temperatures are inadequate, the exposure of various items (including tanks) to solar radiation and high temperatures leads to the view that 60° C (140° F) (as shown in table A-2) is a suitable average temperature to use as a

14/ Second Indorsement, 27 January 1975, to Letter, STEAP-MT-M, APG, to AMSTE-ME (now DRSTE-AD-M, TECOM, 27 November 1974, Subject: Report on Project 9-CO-001-000-063.

15/ Buzzo, B. and Knell, G., Methodology Study of Internal Air and Component Temperatures of Tanks M60 and M55, Yuma Proving Ground, AZ, October 1973.

16/ Suarez, J. A., Methodology Investigation, Third Partial and Final Report - Armored Fighting Vehicle Compartment Temperatures, M60 Tank, Yuma Proving Ground, AZ, November 1974.

storage test temperature for trucks in a "Hot-Dry" climate. Since a vehicle that is in storage (i.e., sitting out in the open) may be started and operated from that position, the temperature at which the vehicle must operate satisfactorily must initially be the same as the storage temperature; however, immediately upon starting the chamber should be reset to the peak air temperature of AR 70-38 (i.e., 49° C (120° F) for hot-dry) and the test continued as the chamber gradually adjusts itself to the new temperature.

On rare occasions a ROC or a DP will specify a "Basic Hot-Dry" climate rather than a "Hot-Dry" climate. AR 70-38 shows that the peak air temperature of the former is 5.6° C (10° F) less than that of the latter: 43° C (109° F) instead of 49° C (120° F). Experience has demonstrated that over such a small range of peak temperatures, if solar radiation remains unchanged, the peak temperature of the materiel will vary by approximately the same amount as the peak air temperature; thus, table A-2 shows a drop of 5.6° C (10° F) for "Basic Hot-Dry" storage as compared to "Hot-Dry."

5. Applicability of MIL-STD-810C and MIL-STD-210B 17/. MIL-STD-810C, Environmental Test Methods, has been the most widely used document describing environmental test procedures. This standard includes high- and low-temperature test procedures designed to accommodate the greatest possible variety of commodities. These procedures, however, have limited usefulness as far as Army vehicles are concerned. The general guidelines, such as those on chamber volume, temperature tolerances, stabilization of temperature, etc., are applicable.

MIL-STD-210B is a DOD document that presents data on climatic extremes; it does not present climatic test procedures. The approach in this standard differs from that in AR 70-38 in that it provides climatic design criteria for military equipment intended for worldwide use; the AR divides the world into eight climatic areas and provides separate design criteria for each area.

The values of MIL-STD-210B are compared with those of AR 70-38 in table A-3. The assumption is made in this TOP that ROCs and DPs will continue to refer to AR 70-38 rather than MIL-STD-210B.

17/ MIL-STD-210B, Climatic Extremes for Military Equipment.

TABLE A-3. COMPARISON OF AR 70-38 AND MIL-STD-210B

Environment	AR 70-38	MIL-STD-210B
Low-temperature operation - extremes	-46° C (-50° F) (cold climate) -51° C (-60° F) (severe cold climate)	-51° C (-60° F) (20% risk)
Low-temperature storage - extremes	-46° C (-50° F) (cold climate)	Not covered
Low-temperature withstanding	Not covered	-67° C (-89° F) (5 years)*
High-temperature operation		
Peak air temperature	49° C (120° F) (hot climate)	49°C (120° F) 1% risk)
Peak solar radiation	1120 w/m^2/hr (355 Btu/ft^2/hr	1120 w/m^2/hr (355 But/ft^2/hr
High-temperature storage (peak)	71° C (160° F) (hot-dry climate)	Not covered
High-temperature withstanding	Not covered	59° C (130° F) (5 years, 10% risk)*

*MIL-STD-210B also provides temperatures for periods other than 5 years.

APPENDIX B
HIGH- AND LOW-TEMPERATURE EFFECTS

1. Types of Problems That Have Occurred at Low Temperatures:

Brittleness of rubber, synthethic rubber, or plastic parts, such as tires, tubes, fan belts, etc.
Congealing of lubricants.
Freezing of coolant.
Freezing of battery liquid.
Stiffness in moving parts.
Binding of metal parts (freezing).
Improper mixture of fuel and air.
Stalling.
Reduction in cupola-and-turret traversing rates.
Reduction in voltage and amperage in electrical system.
Inability of auxiliary power unit (APU) to satisfactorily heat engine coolant, oil sump, and battery box.
Failure or difficulty to start auxiliary engine.
Poor actuation of firing solenoids.
Loss of air in tires.
Inferior performance or failures of lights - searchlights, interior lights, and running lights.
Inferior performance of fire-control system, including rangefinder and computer.
Leakage of brake cups and seals and also plastic piping, etc.
Failure or difficult to start, with and without the aid of priming kit.
Frozen windshield wipers.
Formation of ice in vehicle and on windshield as a result of snow melting and freezing.
Unsatisfactory heating of crew compartment.
Unsatisfactory defrosting.
Reduced effectiveness of blower system. This could result in increased concentration of toxic fumes.
Difficulties with periscopes and telescopes.
Breakdown of communication system.
Human problems related to bulky clothing.

2. Types of Problems That Have Occurred at High Temperatures:

Difficulty in starting engine and auxiliary engine.
Overheating of engines, transmissions, gearboxes, and power steering and hydraulic and cooling systems.
Vapor locks (gasoline engine).
Increased wear.
Improper mixture of fuel and air.
Stalling.
Bending of gun tubes (from sun).

Misalinement of gun and fire-control devices (from sun).
Rapid dissipation of lubricant.
Binding of parts through expansion.
Cracking, checking, and bulging of rubber and plastics.
Permanent set.
Weapon and munition problems (see TOPs in volumes II and III).
Inferior performance of lights.
Inferior performance of fire-control system.
Problems with electrical system.
Boiling of hydraulic brake fluid.
Melting and loss of lubricant.
Discomfort of crew.
Inadequate air conditioning; inadequate ventilation.
Handles too hot to grasp.

APPENDIX C

US AIR FORCE HOT AND COLD FACILITIES

McKinley Climatic Facility, Eglin Air Force Base, Florida.

1. Type: High and low temperature with rain, snow and wind capability.

2. Limits: -53.9° C (-65° F) minimum to +73.8° C (+165° F) minimum. Rain to 15"/hr; Snow 6"/hr; Wind to 100 mph; 10% to 95% RH at 0° to 38° C (32° to 100° F).

3. Chamber Size: 200' wide by 250' long by 35' minimum height.

4. Special Features: Vehicles may be driven without exhaust vent; small caliber firing from within chamber.

APPENDIX D

REFERENCES

1. AR 70-38, "Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions."

2. AR 70-10, "Test and Evaluation During Development and Acquisition of Materiel," 27 December 1972 Draft.

3. AR 1000-1, "Basic Policies for Systems Acquisition by the Department of the Army."

4. AMC Supplement 1 to AR 70-10, "Test and Evaluation During Research and Development of Materiel."

5. AMCP 706-115, "Environmental Series, Part I, Basic Environmental Concepts."

6. MIL-STD-210B, " Climatic Extremes for Military Equipment."

7. MIL-STD-810C, "Environmental Test Methods."

8. DARCOM-P70-1 Research and Development, "DARCOM Test Facilities Register."

9. Feroli, J. A., "Final Report on Special Study of High and Low Temperature Tests of Vehicles, "Aberdeen Proving Ground, Maryland, Report APG-MT-4299 (TECOM Project No. 9-CO-001-000-063).